A REVIEW OF THE ECONOMIC IMPORTANCE OF BLACK FLIES (SIMULIIDAE) IN CANADA[1]

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Chronic outbreaks of Simulium arcticum, S. luggeri *and* S. venustum *from certain large rivers in western Canada killed domestic livestock or reduced their productivity on numerous occasions. These outbreaks also forced uneconomic changes in land use patterns prior to the advent of larviciding. These and other species of simuliids are also pests of man, and still other species are vectors of various avian hematozoa. Leucocytozoan infections have caused massive losses in domestic and wild flocks. Chemical abatement has been used effectively in some regions.*

Souvent, les apparitions chroniques de Simulium arcticum, *de* S. luggeri *et de* S. venustum *dans certaines grandes riviéres de l'ouest du Canada ont provoqué la mortalité des animaux domestiques ou la réduction de leur productivité. A l'époque où les larves ne subissaient pas de traitement insecticide, ces apparitions ont forcé également des perturbations non économiques dans l'agriculture de la région. Ces espèces de simulies et d'autres sont prédateurs aussi des êtres humains, pendant que d'autres espèces encore transmettent plusieurs hématozoaires avicoles. Les infections leucocytozoaires ont occasionné des pertes immenses dans les bandes d'oiseaux domestiques et sauvages. La réduction par moyen chimique a été efficace dans quelques régions.*

INTRODUCTION

An evaluation of the economic effects of black flies cannot be specific for any one species or any one region. Even for outbreaks of *Simulium arcticum* in western Canada, where it has been possible to estimate fatalities with some precision, there were unrecorded losses of even larger proportions, such as reduced productivity, and subtle shifts in land use on individual farms from livestock-based to less productive enterprises.

Immature stages of black flies are restricted to flowing water and one species or another live in practically every stream and river in the world. Fortunately most species are innocuous, and of the blood-seeking species adults of only a few are abundant enough to be considered pest species. This is because the immature stages of most species are restricted in distribution, and because they are relatively specific as to the kinds of streams or rivers they inhabit and in details of development and seasons of major abundance. Adults also vary specifically in flight, mating and oviposition behaviour, in host selection and in many other factors that affect their potential as pests.

In the main, the northern limit for black fly problems is the southern edge of the tundra. Adults occasionally are pestiferous in certain areas of the tundra but such black flies originate mainly in large rivers such as the Mackenzie and the Churchill which flow northward from the forested areas. Adults of the relatively few species breeding in tundra streams seem to be mainly autogenous - that is, capable of producing eggs from nutrients stored in larvae. Species with biting adults are restricted almost entirely to rivers and streams in the forested and prairie areas of Canada, coinciding exactly with the areas favoured by man for his major endeavours. The black fly fauna in some areas is changing, presumably in response to environmental changes.

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In this review of the economic aspects of black fly outbreaks I discuss black flies in Canada first as pests of non-hominid animals, second as pests of man, and finally as vectors of hematozoan diseases of birds and mammals. I cannot claim field experience with eastern Canadian problems and thus have depended upon the experiences of Drs. A.S. West, A.M. Fallis, G.F. Bennett and others in preparing this review.

BLACK FLIES AS PESTS OF NON-HOMINID ANIMALS

The major problem species in western Canada is *Simulium arcticum*. Domestic livestock were killed in outbreaks in Saskatchewan at least as early as 1886 - some 15 to 25 years before agricultural settlement became general. Since then, outbreaks have reoccurred almost every year with fatalities in perhaps more than half of those years up until 1948 when chemical larviciding was initiated in tests conducted by our Research Station (Arnason *et al.* 1949).

Immature stages of *S. arcticum* are widely distributed in streams and rivers of the western plains, mainly those east of the continental divide from the tundra south into Arizona (Stone 1965).Occasional outbreaks of this or a related species occur west of the divide (Curtis 1954) but the major outbreaks of *S. arcticum* originate in the large, silty rivers flowing eastward and northward from the mountains in Canada (Fig. 1).

Fig. 1. Areas of Saskatchewan and Alberta subjected to occasional outbreaks of the black fly, *Simulium arcticum* Mall.

The area in Saskatchewan where outbreaks have occurred includes at least 75,000 km^2, with the largest single outbreak, that of 1946, enveloping about one half of this. The major outbreaks occurred between mid-May and the end of June. Minor outbreaks often occurred in August and September (Cameron 1922).

It was impossible to predict precisely times and places where outbreaks would occur, because these depended upon river conditions throughout the spring, and upon weather conditions after emergence.

The most severe outbreaks originated in strong rapids in the lower sections of the North and South branches of the Saskatchewan River, in a portion of the North Saskatchewan in Alberta, and from large, strong rapids in the mid sections of the Athabasca River.

These are large rivers of silty water, widely fluctuating volumes, and boulder-strewn beds, entirely lacking in emergent vegetation and subject to severe ice scouring each spring. Aquatic stages of *S. arcticum* are uniquely adapted to these conditions. Eggs are dropped singly onto the river surface and accumulate in the river bed where they overwinter (Fredeen *et al.* 1951). They commence to hatch soon after the ice breaks up in the spring and the larvae then drift downriver to attach to rocks and thus become highly concentrated in large rapids. Larvae are efficient filter feeders (Fredeen 1964). Females are apparently autogenous under certain conditions (Fredeen 1963) and fly upriver to deposit eggs.

In the most compact colonies of larvae and pupae 70 to 80 have been counted per cm^2. A single rapids extending 425 m across the entire North Saskatchewan River in 1947 was estimated to contain more than 30×10^7 larvae and pupae per m of river length. With at least 320 km of river partly filled with rapids capable of supporting such large numbers it was no wonder that outbreaks could spread into such wide areas of Saskatchewan. I estimate that if the production of blood-seeking black flies in 1947 was only about 0.1% of this, about 500, 000 litres of blood could have been extracted from livestock in the outbreak area (an average of about 2 litres per animal if there were 250,000 animals in the area).

On the western Canadian prairies, and perhaps in all of Canada, *S. arcticum* is the only species known to cause livestock fatalities by direct poisoning. Until recent years veterinarians were reluctant to admit that these black flies could kill livestock. Direct evidence of the relationship was very difficult to obtain since the black flies that inflicted a fatal illness disappeared many hours before an animal died.

The losses in 1886, reported to me by the late Mr. J.T. Mawson of Dundurn, included six cattle, two horses and an ox from farms 25 miles south of Saskatoon. Undoubtedly that outbreak was widespread but very little of the area had been settled at that time. Cameron (1918) reported that about 100 cattle died during an outbreak near Duck Lake in 1913 but Rempel and Arnason (1947) reported that about 300 died in Saskatchewan that year. They also reported that losses were heavy again in 1919 and in 1930, and described outbreaks in central Saskatchewan that killed at least 133 domestic animals worth some $20,000 in 1944, at least 70 animals worth an estimated $7,000 in 1945 and at least 600 animals worth $70,000 in 1946. Additional losses of at least 210 animals occurred in widespread outbreaks in 1947.

In the 29 years since black fly larviciding was initiated in 1948 about 125 animals have been killed by black flies in Saskatchewan. These black flies generally emerged from untreated sections of the Saskatchewan River.

In Alberta a few losses are said to have occurred during black fly outbreaks near Minburn in 1956 and again in 1961. Near Athabasca black flies inflicted losses in 1955 or 1956, in 1963 and 1964 (Fredeen 1969) and apparently in 1971 and 1972. Adults of an unknown species near *S. arcticum* (possibly *S. defoliarti*) also occasionally damage livestock on ranches adjacent to certain rivers in central British Columbia and larviciding was required in 1953 after losses of over $24,000 occurred in 1952 (Curtis 1954).

It is presumed that many unreported losses occurred in all of these areas in earlier years. Even Cameron (1922) who described severe outbreaks in Saskatchewan in the years 1917 to 1921 did not mention fatalities. Recorded losses in the final four years before initiation of chemical larviciding in 1948 included more than 1,000 domestic animals. More than 600 of these were killed in the first four days of a single outbreak lasting several weeks in 1946

(Rempel and Arnason 1947). The most serious aspects of these outbreaks were the losses of herd sires. These were generally purebred, and were costly and difficult to replace during breeding seasons. In herds attacked in a 1500 km^2 area in 1944, 28% of all the bulls were lost, 7.4% of the cows, 2.2% of the yearlings and only 0.3% of the calves. Newborn calves were highly susceptible, at least until they had gained some immunity from their mother's colostrum. There were also losses of horses, sheep, swine and even wild deer.

Losses more difficult to assess included weight losses, or in the least-unrealized weight gains, reductions in milk production of up to 50%, and reductions in breeding activities. Bulls ceased breeding and many suffered infections of the sheath because *S. arcticum* adults feed mainly along the underlines of animals. Some bulls were said to have been permanently sterilized. Delays in calving during the following year meant lighter weaning weights in the fall. *S. arcticum* adults also attached chickens. Egg production in one flock fell by 16% during one outbreak as indicated by official "Records of Performance" data.

Normally *S. arcticum* adults do not bite people but during severe outbreaks people were bitten and driven indoors and many required medical attention. Even a single bite could impair blood circulation in a limb. One man was hospitalized for several months due to allergic reactions comparable to Arthrus' syndrome (Fredeen 1969).

Long-term economic declines occurred in affected regions when livestock producers suffered heavy losses and often shifted to less productive enterprises rather than face the uncertainties of continued outbreaks. Large portions of the affected areas were actually best suited to forage crops and except for the presence of black flies, to livestock enterprises, and after 1948 they were converted back to those uses.

Animal fatalities were attributed mainly to direct toxemia and shock. Newborn calves and imported animals such as bulls were highly susceptible. Animals quickly developed immunity and those raised in outbreak areas were relatively resistant to poisoning. Despite resistance, however, animals generally sought protection during outbreaks.

Symptons of toxemia developed rapidly, and within a few hours after the onset of a massive attack animals commenced to develop fluid-filled swellings along the underlines. In less resistant animals this was followed by rapid, laboured breathing, trembling of the muscles and death within minutes or hours (Millar and Rempel 1944). Post mortems showed fluid-filled lungs and body cavities, and death was attributed to shock, heart failure and mechanical pneumonia. Resistant animals recovered completely within 48 hours or more.

Protection of range animals was difficult. If allowed access to shelters the cattle spent entire days in them. *S. arcticum* adults will not enter a darkened shelter even if open on one side. Cattle in open pastures sought shelter in sloughs where they stood in deep water to protect their underlines. Others lay down much of the time for the same reason, or vainly sought shelter in brush. Most farms had smudges burning once an outbreak started and the cattle quickly learned to use these. However, the main damage was often inflicted without warning during the first evening and early morning of an outbreak. Depending upon wind directions and other weather conditions outbreaks took place in one area for awhile and then were transferred to entirely new areas sometimes 100 miles distant by changes in the wind. Cold rainy weather brought relief but in some instances this was only temporary.

Such outbreaks, unpredictable in time and place, created great suspense throughout entire black fly seasons but now larval populations can be monitored and larvicide applied as required. Livestock men in Saskatchewan have come to depend upon larviciding for preventing outbreaks. Thus for the time being we are committed to larviciding occasionally as required, as the least costly form of insurance available. I am not convinced that larviciding is the final answer but so far alternatives have not been found. Meanwhile river conditions are gradually changing and perhaps as a result numbers of *S. arcticum* larvae, even in untreated portions of the Saskatchewan River, have recently declined and the numbers of *S. luggeri* larvae in this river have increased.

In 1964 a hydroelectric irrigation dam on the South Saskatchewan River was used to impound water for the first time. Final closure occurred in 1968 and the summertime river volumes have been drastically reduced almost every year since then. *S. luggeri* larvae were first detected in the South Saskatchewan in 1968 and three years later adults emerged in sufficient numbers to harass livestock in adjacent pastures. Since then, for reasons yet unknown, numbers of larvae inhabiting the South Saskatchewan River have declined to the extent that *S. luggeri* outbreaks from that source no longer seem to pose a threat.

In the North Saskatchewan River a more intensive change is occurring. The last massive outbreaks of *S. arcticum* from that river occurred in 1972 and by 1975 and 1976 larvae were scarce. *S. luggeri* larvae began to appear in increasing numbers in 1971 and in 1975 these black flies emerged in such abundance as to cause alarm in widespread areas. During the spring and summer of 1976 adult populations were even larger, and repeated severe outbreaks from May to October created about as much reaction from livestock owners as did the most severe outbreaks of *S. arcticum* in the past 30 years.

During the past two years the North Saskatchewan, like the South branch in 1968, suffered drastic summertime reductions in volumes due mainly to reduced precipitation in its watershed. When the volume was low the water was relatively clear and warm. Presumably this allowed increased production of phytoplankton but this was not measured in 1976. I think as long as these river conditions prevail we should expect relatively large numbers of *S. luggeri*, but hopefully smaller numbers of *S. arcticum*.

Previously *S. luggeri* larvae were restricted to permanently-flowing, clear-water rivers in the prairie provinces and in the adjacent States. Thus the recent changes in the Saskatchewan River appear to have been "made to order" for this species.

The egg-laying habits of *S. luggeri* females have allowed them to adapt to the Saskatchewan River in that they bomb their eggs individually onto the water surface. (There is no emergent vegetation to serve as substrates for egg masses.) The eggs settle to the river bed where they hatch within a few days. With the onset of cooler temperatures in the fall embryonic development ceases until spring. The species apparently overwinters only as eggs in this river.

Fortunately the toxins injected by *S. luggeri* females are less toxic than those of *S. arcticum*. To date there is no sound evidence that cattle have been fatally poisoned by this black fly. However, potentially, *S. luggeri* adults may be more dangerous than those of *S. arcticum* for at least three reasons:-

1. *S. luggeri* is capable of repeated life cycles spaced about four weeks apart throughout the summer. In 1976 at least five life cycles were completed. Adults from the first cycle created some havoc in early June but this was nothing to compare with the damage done during the second and third generations in July and August. Each of these two latter outbreaks lasted about three weeks and these black flies eventually covered an area of about 18,000 km^2.
2. Attacks by *S. luggeri* adults are relatively dangerous because blood-seeking females swarm densely around the heads of animals, driving them into stampedes. Cattle are severely bitten around the eyes. In contrast, *S. arcticum* females attack along the underline and are thus much less alarming to the animals.
3. *S. luggeri* females are also relatively dangerous because they attack man as well as four-legged beasts whereas *S. arcticum* females rarely bite man.

Losses as a result of these outbreaks in 1976 were undoubtedly large, but impossible to sum up in terms of dollars and cents:-

1. Human activities were disrupted severely. Even repellents did not entirely prevent these black flies from swarming like angry wasps around one's head. Farm work, gardening and

recreation were neglected. Many people required medical aid.
2. Hyperactivity of livestock caused much concern among owners with the result that normal farming needs were neglected. Hay and grain crops were reduced in yield and quality because of inadequate attention.
3. Fences were pushed over by stampeding cattle. One farmer reported that a half mile of fencing had to be rebuilt. Straying herds had to be rounded up.
4. Breeding activities of bulls and cows were repeatedly disrupted throughout the summer. This will cause financial losses if cows are late calving in 1977 and weaned calves are lacking adequate growth when sold.
5. Unrealized weight gains were another aspect. Some livestock owners claimed that even immature animals lost weight on pasture.
6. Animal fatalities were a minor part of the losses. Perhaps two to three dozen animals were killed or had to be destroyed as a result of damages incurred by trampling. Mainly calves were lost.
7. Because of apprehension about similar outbreaks in the future some farmers have already commenced shifting from livestock to cereal crop enterprises, even though optimum exploitation of the land and climatic conditions suggest otherwise.

A third species of some importance to livestock producers in western Canada is *S. venustum*. Occasionally, lake-fed rivers on the Great Plains overflow their banks mainly due to excessive runoff following snow melt in the spring. When grassy valley floors are submerged under fast-flowing water for several weeks in spring they become heavily colonized with the larvae of *S. venustum*, *S. luggeri*, *S. vittatum* and other species. In such years these three species, but especially *S. venustum*, have severely attacked livestock and people within at least 2 miles on either side of the river. These outbreaks normally do not cause fatalities but nevertheless create intolerable conditions for man and other animals for many days. Dairy farmers have claimed reductions in milk production of about 50% during the periods when their cattle were forced indoors (Fredeen 1956-1958).

BLACK FLIES AS PESTS OF MAN

Simulium venustum is the notorious "white-stockinged" black fly pest of man and other animals in woodlands of the Canadian Shield. The Precambrian Shield occupies about 50% of Canada extending from the Atlantic Ocean to the Mackenzie River, and its southern portions are crossed by swift lake-fed streams and rivers suitable for production of large numbers of the *S. venustum* complex. Larvae of this species complex also occur abundantly at times in small rivers on the Great Plains and in British Columbia (Hearle 1932). There other animals seem to be attacked more readily than man.

About 10 other species are lesser pests. The "*Prosimulium hirtipes*" complex (especially *P. fuscum* and *P. mixtum*) (Davies 1961) are early spring species preceding *S. venustum* on the Canadian Shield. *P. fulvum* is restricted to the western mountains where blood-seeking females are nuisances during occasional warm days in July and August. *S. decorum* breeds abundantly in and below beaver dams, and the adults along with those of *S. tuberosum*, (and *S. parnassum* in eastern Canada) occasionally occur in the attacking swarms of *S. venustum*. On the western plains *S. luggeri* and *S. arcticum* are locally abundant and bothersome. The small yellowish adults of *S. griseum* are occasionally bothersome at Medicine Hat, Alberta. The larvae of *S. griseum* occur mainly in the rivers of southern Alberta. Finally, I should include *S. vittatum* adults which often swarm densely about humans although they do not normally bite. It is often the predominant species in an attendant cloud of black flies especially on the Precambrian Shield. With only the occasional specimen of *S. venustum* in the same cloud, the uninitiated person fears that the whole cloud is about to descend upon him for blood meals. *S. vittatum* larvae overwinter, with pupation synchronized to allow mass emergence of adults soon after the ice breaks up in the spring. Most complaints about *S. vittatum* occur during these few days. It is multivoltine, however, and thus adults can also be abundant for extended periods of time in late summer.

During the past 60 years the pace of economic exploitation and settlement of the Precambrian Shield has steadily accelerated. Development has been particularly rapid along the north side of the St. Lawrence River, extending perhaps 600 km inland. Where formerly there were only a few fishing villages and small pulp mills dependent upon winter cutting, now there are large pulp and paper industries dependent upon year round cutting, as well as hard-rock mines and immense hydroelectric developments. There are modern cities, refining and construction industries and a large tourist trade. Human settlements are often concentrated near black-fly breeding rivers (how can they avoid such sites) and, as well, outdoor activities are concentrated during the summertime black-fly breeding seasons.

Wolfe and Peterson (1959) reported that the principal man-biting species in the Baie Comeau area of Quebec included the "*P. hirtipes*" complex in the early spring and *S. venustum* throughout the summer. West *et al.* (1960) reported high landing rates for extended periods of time from mid-June to mid-August, but especially from late June to mid-July and again in late July. Peterson and Wolfe (1956-1958), Davies *et al.* (1961-1962) and others considered that *S. venustum* was the most serious black-fly, if not biting-fly, pest in Ontario and Quebec.

Black flies undoubtedly are the major biting-fly pests on the Shield. Whereas mosquitoes occasionally create problems, black flies are said to be always "bad" but in some years "worse" (West 1961). In pulpwood cutting areas it was generally agreed that black flies were the main reason for low efficiency and for the high rates of labour turnover during the summer months (West 1977). About 20 years ago abatement programs were developed and became commonplace in pulp cutting areas. Abatement measures were written into some labour contracts.

I do not have data evaluating effects of black flies on man's activities. Individuals vary so much in their tolerances and in their abilities to understand the problems and protect themselves. It would be very difficult to estimate unrealized tourist trade and impossible to estimate effects on resident family members whose normal outdoor and recreation activities are curtailed, not only by black flies but other biting flies as well.

Because stories about black flies are often enhanced in the telling, some tourists develop unrealistic fears of black flies and cannot enjoy an outing "in the north" without major preparations. Some years ago I was in a small holiday group enjoying breakfast in the open and without repellents in peaceful surroundings north of the Churchill River in Saskatchewan. Sounds coming from a nearby trailer indicated that someone else would also appear soon. Out stepped a person dressed as if prepared for a trip to the moon, completely enveloped in insect-proof clothing including a head net. It sprayed itself with an aerosol can from head to toe and then knocked on the door to summon another person out, similarly attired. The newcomer was also sprayed from head to toe despite the fact that we were sitting nearby, completely free of insects. Their anxiety was impressive.

In some areas of Canada problems concerning black flies may be more fancied than real, especially for tourists. Nevertheless there are areas of the Canadian Shield where man requires considerable protection from black flies during the summer.

BLACK FLIES AS VECTORS OF DISEASES

This is a very complex subject and I will treat it very briefly by reviewing major experimental facts, observations and reviews published mainly during the last two decades.

Many bird-biting species of simuliids are well-known vectors of various avian hematozoa, leucocytozoons in particular, but also including trypanosomes and microfilaria (Fallis 1964). Anderson *et al.* (1961) isolated Eastern Equine Encephalitis virus from one pool of each of *S. johannseni* and *S. meridionale*. Black flies have the capability of transmitting the virus that causes myxomatosis in rabbits, as experiments have shown.

Various species of *Onchocerca* transmitted by simuliids are notorious pests of man in certain tropical regions and animals on all continents. In the Western Hemisphere north of central America infections occur only in non-hominid animals. In Alberta and British Columbia there are scattered reports by veterinarians of onchocerciasis in horses (Wobeser 1977). The horses are brought into clinics for treatment of chronic skin conditions but are not disabled by the disease. Leg worms, *Onchocerea (=Wehrdikmansia) cervipedis*, in moose and elk have been reported in the prairie provinces. However, the vectors are not yet proven to be restricted to the Simuliidae.

Anderson (1956) described the life cycle and transmission of *Ornithofilaria fallisensis*, a parasite of domestic and wild ducks in Ontario. He reported that the microfilariae developed to the infective stage in *S. venustum, S. parnassum, S. rugglesi, S. euryadminiculum, S. croxtoni* and *S. latipes*. Microfilariae are also transmitted by ceratopogonids and culicids. They have been reported from blood of birds in the Cathartidae, Corvidae, Tetraonidae, Turdidae and Tyrannidae, but rarely in members of other families of North American birds (Greiner *et al.* 1975).

Trypanosomes are also transmitted by a variety of vectors including simuliids. Bennett (1961) proved that ornithophilic simuliids were natural vectors of trypanosomes in Algonquin Park, Ontario, and that a single species of *Trypanosoma* could infect several species of birds. Trypanosomes have been reported in blood samples from over 32% of the Bombycillidae, 10% of the Corvidae, 19% of the Cuculidae, 10% of the Laniidae, 10% of the Paridae, 16% of the Sittidae, 21% of the Tetraonidae, 18% of the Thraupidae, 19% of the Vireonidae but rarely in other orders (Greiner *et al.* 1975).

The main simuliid-transmitted parasites in Canada are the various species of *Leucocytozoon*. All are parasitic only in birds. Wickware (1915) described *L. anatis* and determined that it caused a fatal disease of ducks in Ontario. O'Roke (1934) published a report of the life cycle of this species and proved that it was transmitted by black flies in Michigan. He also showed that the disease was not uniformly distributed in nature and that it was rapidly fatal to wild and domestic ducklings. Fallis and Bennett (1966) reported that one species of *Simulium* could transmit several species of *Leucocytozoon* and one species of *Leucocytozoon* could be transmitted by several species of black flies.

In their recently published checklist of avian hematozoa in North America, Greiner *et al.* (1975) recorded that the highest leucocytozoan infection rates in wild birds in all of North America occurred in the western and eastern mountainous regions of Canada. In the western mountains about 45% of all birds examined carried this hematozoan in the blood, and in the eastern Appalachian-Laurentian mountains about 23%. In the Central Plains only about 2% were infected and no infected birds were reported from the Arctic. These regional differences in infection rates are related mainly to distribution of the various bird-biting species of simuliids which alone are the vectors, and the accessibility of the host species of birds (Greiner *et al.* 1975).

The bird-biting species of simuliids develop mainly in small streams. However, *S. rugglesi* which is distributed from Labrador and Maine westwards to Alberta, and *S. meridionale*, which is distributed throughout the mid continent from Mexico north to the tundra (Shewell 1956-1958), are river-breeding species and their adults are probably responsible for the occasional massive losses of domestic poultry that have occurred mainly in agricultural areas.

Savage and Isa (1945) reported that leucocytozoan infections killed 5,000 turkeys out of a flock of 8,000 located near the Assiniboine River in Manitoba. Laird and Bennett (1970) indicated that leucocytozoan infections were responsible for massive losses of domestic geese at Fort Chimo on Ungava Bay. I have personally heard of losses of chickens, ducks and geese, generally long after the events have occurred when it is impossible to establish the causes. Poultry producers should realize that if they establish ranches near streams or rivers they will have to be prepared to occasionally protect their birds from black flies.

I have not heard of massive losses in the western mountainous regions despite relatively high infection rates there in wild birds. The small streams there would not be conducive to massive black fly outbreaks, and also adults of the species of black flies, mainly *Eusimulium*, do not disperse widely from their breeding places.

Mortality rates in mature wild birds seem to be generally low but actually very few experimental data are available. Clarke (1936) and Fallis (1945) showed that when the numbers of ruffed grouse declined rapidly in Ontario in 1933-34 and again in 1941-43, the percentages of grouse infected by *Leucocytozoon* and other hematozoa were high (up to 67% for *Leucocytozoon* alone). Fallis and Bennett (1958), however, could produce only low parasitemias in captive ruffed grouse, naturally infected by large numbers of vector species, and also did not detect gross signs of disease. Bendell (1955), following studies of a population of blue grouse on Vancouver Island, reported that percentage infection rates in chicks and in older grouse (bracketed) were as follows: with *Haemoproteus* 66 (97), *Leucocytozoon* 38 (85), *Trypanosoma* 20 (77) and microfilariae 0 (80). These parasitic hematozoa were considered to be factors in chick mortalities but not in yearling or adult mortalities.

Massive losses of young wild ducks and geese due to leucocytozoan infections were reviewed by Bennett and MacInnes (1972) and by Herman, Barrow and Tarshis (1975). The latter reported that goslings, mainly 2 to 7 weeks old, on the Seney National Wildlife Refuge in northern Michigan suffered average annual losses of 16 to 87% during a 13-year period. Their research indicated that *L. simondi* was responsible for most of these losses.

CONCLUSIONS

In conclusion this has been a brief review of a very complex subject. The bibliography will provide much additional information and there are many more references I could have included.

Until recently people accepted black fly outbreaks as part of the natural hazards they had to face. They had no alternatives but to cope individually as best they could. Today people are generally aware of the potential sources of these outbreaks and have come to depend upon group action to demand abatement plans, administered by professionals, as forms of insurance. I think that we have the responsibility to allay fears, and thus when livestock men, resort people, unions or managers of wildlife refuges come seeking help, their problems should be thoroughly investigated by experienced professionals. Beneficial and efficient managment schemes, if required, can be developed only in this way. Each plan must be precisely tailored for each specific problem. Furthermore, an abatement plan should be revised annually with regard to (a) actual needs which are subject to change, and (b) new research data, to ensure maximum benefits and minimal environmental damage. Unfortunately, such studies could be time-consuming and expensive, possibly in some situations more expensive than the losses caused by the black flies.

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REFERENCES

Anderson, J.R., V.H. Lee, S. Vadlamudi, R.P. Hanson & G.R. DeFoliart. 1961. Isolation of Eastern Encephalitis virus from Diptera in Wisconsin. Mosquito News 21: 244-248.

Anderson, R.C. 1956. The life cycle and seasonal transmission of *Ornithofilaria fallisensis* Anderson, a parasite of domestic and wild ducks. Canadian Journal of Zoology 34: 485-525.

Arnason, A.P., A.W.A. Brown, F.J.H. Fredeen, W.W. Hopewell & J.G. Rempel. 1949. Experiments in the control of *Simulium arcticum* Malloch by means of DDT in the Saskatchewan River. Scientific Agriculture 29: 527-537.

Bendell, J.F. 1955. Disease as a control of a population of blue grouse, *Dendragapus obscurus fuliginosus* (Ridgway). Canadian Journal of Zoology 33: 195-223.

Bennett, G.F. 1961. On the specificity and transmission of some avian trypanosomes. Canadian Journal of Zoology 39: 17-33.

Bennett, G.F. & C.D. MacInnes. 1972. Blood parasites of geese of the McConnell River, N.W.T. Canadian Journal of Zoology 50: 1-4.

Cameron, A.E. 1918. Some blood-sucking flies of Saskatchewan. Agricultural Gazette of Canada 5: 556-561.

Cameron, A.E. 1922. The morphology and biology of a Canadian cattle-infesting black fly, *Simulium simile* Mall. (Diptera, Simuliidae). Canada Department of Agriculture, Bulletin No. 5 - New Series, 26 p.

Clarke, C.H.D. 1936. Fluctuations in numbers of ruffed grouse, *Bonasa umbellus* (L.) with special reference to Ontario. University of Toronto Studies, Biological Series 44: 1-118.

Curtis, L.C. 1954. Observations on a black fly pest of cattle in British Columbia (Diptera: Simuliidae). Proceedings of the Entomological Society of British Columbia 51: 3-6.

Davies, D.M., B.V. Peterson & D.M. Wood. 1961 (1962). The black flies (Diptera: Simuliidae) of Ontario. Part 1. Adult identification and distribution with descriptions of six new species. Proceedings Entomological Society of Ontario 92: 70-154.

Davies, L. 1961. Ecology of two *Prosimulium* species (Diptera) with reference to their ovarian cycles. Canadian Entomologist 93: 1113-1140.

Fallis, A.M. 1945. Population trends and blood parasites of ruffed grouse in Ontario. Journal of Wildlife Management 9: 203-206.

Fallis, A.M. 1964. Feeding and related behavior of female Simuliidae (Diptera). Experimental Parasitology 15: 439-470.

Fallis, A.M. & G.F. Bennett. 1958. Transmission of *Leucocytozoon bonasae* Clarke to ruffed grouse (*Bonasa umbellus* L.) by the black flies *Simulium latipes* Mg. and *Simulium aureum* Fries. Canadian Journal of Zoology 36: 533-539.

Fallis, A.M. & G.F. Bennett. 1966. On the epizootiology of infections caused by *Leucocytozoon simondi* in Algonquin Park, Canada. Canadian Journal of Zoology 44: 101-112.

Fredeen, F.J.H., J.G. Rempel & A.P. Arnason. 1951. Egg-laying habits, overwintering stages and life cycle of *Simulium arcticum* Mall. (Diptera: Simuliidae). Canadian Entomologist 83: 73-76.

Fredeen, F.J.H. 1956 (1958). Black flies (Diptera: Simuliidae) of the agricultural areas of Manitoba, Saskatchewan and Alberta. Proceedings Tenth International Congress of Entomology, Montreal 3: 819-823.

Fredeen, F.J.H. 1963. Oviposition in relation to the accumulation of bloodthirsty black flies (*Simulium (Gnus) arcticum* Mall. (Diptera)) prior to a damaging outbreak. Nature (London) 200: 1024.

Fredeen, F.J.H. 1964. Bacteria as food for blackfly larvae (Diptera: Simuliidae) in laboratory cultures and in natural streams. Canadian Journal of Zoology 42: 527-548.

Fredeen, F.J.H. 1969. Outbreaks of the black fly *Simulium arcticum* Malloch in Alberta. Quaestiones Entomologicae 5: 341-372.

Greiner, E.C., G.F. Bennett, E.M. White & R.F. Coombs. 1975. Distribution of the avian hematozoa of North America. Canadian Journal of Zoology 53: 1762-1787.

Hearle, Eric. 1932. The black flies of British Columbia (Simuliidae, Diptera). Proceedings of the Entomological Society of British Columbia 29: 5-19.

Herman, C.M., J.H. Barrow & I.B. Tarshis. 1975. Leucocytozoonosis in Canada geese at the Seney National Wildlife Refuge. Journal of Wildlife Diseases 11: 404-411.

Laird, M. & G.F. Bennett. 1970. The subarctic epizootiology of *Leucocytozoon simondi*. Journal of Parasitology 56: 198.

Millar, J.L. & J.G. Rempel. 1944. Livestock losses in Saskatchewan due to black flies. Canadian Journal of Comparative Medicine and Veterinary Science 8: 334-337.

O'Roke, E.C. 1934. A malaria-like disease of ducks caused by *Leucocytozoon anatis* Wickware. University of Michigan School of Forestry and Conservation, Bulletin 4: 44 p. 3 pl.

Peterson, D.G. & L.S. Wolfe, 1956 (1958). The biology and control of black flies (Diptera: Simuliidae) in Canada. Proceedings Tenth International Congress of Entomology, Montreal 3: 551-564.

Rempel, J.G. & A.P. Arnason. 1947. An account of three successive outbreaks of the black fly, *Simulium arcticum*, a serious livestock pest in Saskatchewan. Scientific Agriculture 27: 428-445.

Savage, A. & J.M. Isa. 1945. Case report. An outbreak of *Leucocytozoon* disease in turkeys. Cornell Veterinarian 35: 270-272.

Shewell, G.E. 1956 (1958). Classification and distribution of arctic and subarctic Simuliidae. Proceedings Tenth International Congress of Entomology, Montreal 1: 635-643.

Stone, A., C.W. Sabrosky, W.W. Wirth, R.H. Foote & J.R. Coulson. 1965. A catalogue of the Diptera of America north of Mexico, United States Department of Agriculture, Agriculture Handbook No. 276, 1696 p.

West, A.S. 1961. Biting fly control on the Quebec north shore. Proceedings 48th Annual Meeting of the New Jersey Mosquito Extermination Association: 87-95.

West, A.S. 1977. Manager, Environmental Policy, Newfoundland and Labrador Hydro, St. John's, Newfoundland. Personal communication.

West, A.S., A.W.A. Brown & D.G. Peterson, 1960. Control of black fly larvae (Diptera: Simuliidae) in the forests of eastern Canada by aircraft spraying. Canadian Entomologist 92: 745-754.

Wickware, A.B. 1915. Is *Leucocytozoon anatis* the cause of a new disease in ducks? Parasitology 8: 17-21.

Wobeser, G. 1977. Western College of Veterinary Medicine, Saskatoon, Saskatchewan. Personal communication.

Wolfe, L.S. & D.G. Peterson. 1959. Black flies (Diptera: Simuliidae) of the forests of Quebec. Canadian Journal of Zoology 37: 137-159.